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Selectivity of m.f. transistor portable receivers

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RESEARCH DEPARTMENT

SELECTIVITY OF M.F. TRANSISTOR PORTABLE RECEIVERS

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SELECTIVITY OF M.F. TRANSISTOR PORTABLE RECEIVERS

Summary

Subjective measurements have been made in the laboratory on ten transistor portable receivers of current and recent type to determine their selectivity on the m.f. band, and the extent to which they might suffer overloading by strong local signals. The investigation covered frequency spacings between the wanted and interfering transmissions of from 9 kHz to approximately 250 kHz.

The majority of the receivers could accept a wanted signal of about 200 mV/m without significant distortion caused by overloading. An unwanted strong signal would not produce noticeable interference in the majority of receivers provided that it was spaced by more than 6% in frequency from the wanted signal and did not exceed 1 V/m in strength.

1. Introduction

It is possible that a number of m.f. local radio stations will be erected in the U.K. in the near future. These stations would be sited in or near to large towns and could produce field strengths of the order of 1 V/m in areas containing a significant number of listeners. For such a local radio network to be properly planned it would be necessary to have information on the ability of typical domestic receivers to reject interference from unwanted transmissions of very high field strength even although the frequency spacing between the wanted and interfering transmissions were sufficiently large to be outside the range where selectivity is normally considered to be a problem.

2. Conditions of test

All of the tests were carried out in the laboratory, the wanted and interfering transmissions being simulated by means of signal generators. The receiver under test was placed in an electrically screened but acoustically transparent enclosure[1] within which signal fields of known strengths could be produced.

Ten receivers were used in the tests, all transistor portables of current and recent types, and are identified in this report by the letters A to K (excluding I). The letters are allocated in order of price, A being the most, and K the least expensive. Receivers A, B, E, F and H incorporated a v.h.f. f.m. range and, in order to make a fair comparison of price between the a.m./f.m. and a.m. only receivers, an arbitrary estimated allowance for the cost of providing the f.m. range was made. On the basis of this notional a.m. receiver price, receivers A to E come into the medium to higher range from £22 to £14 and receivers F to K in the cheaper range from £7 to £3.

The main tests of selectivity were carried out, with a wanted signal having a frequency of 1250 kHz and a field strength of 10 mV/m, on all ten receivers by six observers. For each test the receiver under investigation was placed in the screened enclosure, the wanted signal was applied and the observer was asked to tune the receiver and adjust the volume control. The interference field was then applied and at each frequency spacing investigated its level was adjusted by the observer until the impairment that it produced was assessed by him as Grade 2 on the EBU six-point impairment scale,* i.e. as 'just perceptible'. This process was repeated with each observer in turn.

Some subsidiary tests were made in a similar manner to determine:—

(i) selectivity with a wanted signal frequency of 700 kHz,

(ii) the effect of wanted signal field strength on selectivity,

(iii) the maximum wanted signal field strength receivable without objectionable distortion,

(iv) the variation of impairment with level of interfering signal field strength,

(v) the effect of partially exhausted batteries.

These subsidiary tests were made with fewer receivers and/or observers; the details are given with the individual test results.

* The grades on the EBU six-point impairment scale are:
1 - Imperceptible
2 - Just perceptible
3 - Definitely perceptible but not disturbing
4 - Somewhat objectionable
5 - Definitely objectionable
6 - Unusable

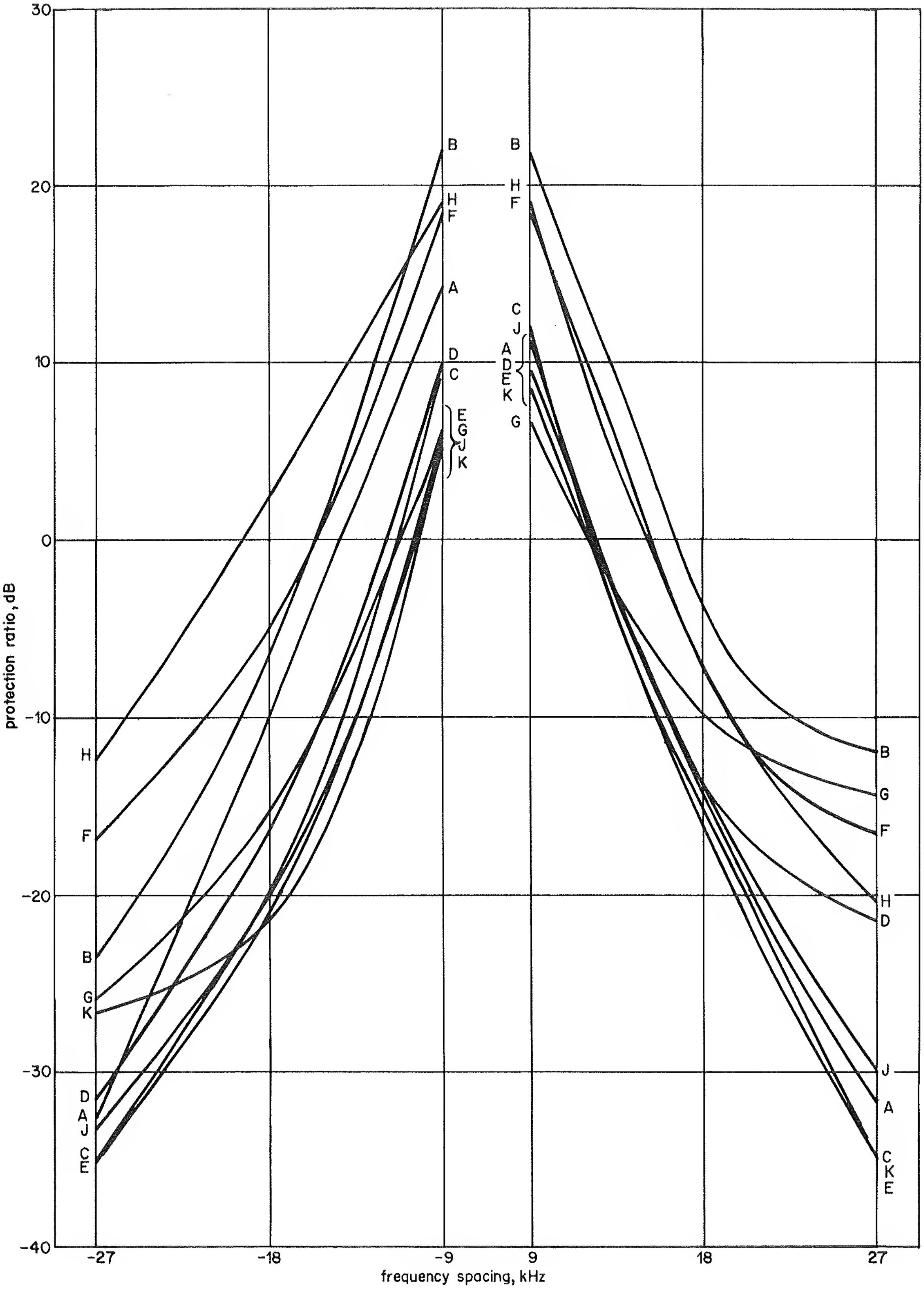

Fig. 1 - Close-channel protection ratio for Grade 2 interference

Wanted signal frequency = 1250 kHz Wanted signal field strength = 10 mV/m

The wanted programme material for all tests was male speech — a recording of a broadcast news bulletin — and the interfering programme material was a recording of light orchestral music. Both programmes were compressed 12 dB before modulation.

The panel of observers consisted of four engineers and two non-technical persons; four of these were in the 20 to 30 year old age group and two in the 40 to 50 year old group.

3. Test results and discussion

The results of the selectivity tests are presented in two groups, close-channel selectivity covering the range of frequency spacings up to ±27 kHz and remote-channel covering the range from 50 kHz upwards.

3.1. Close-channel selectivity test results

Measurements were made with wanted-to-interfering signal frequency spacings of 9 kHz, 18 kHz and 27 kHz. The results obtained with a wanted-signal frequency of 1250 kHz and field strength of 10 mV/m are given in Fig. 1 in terms of the wanted-to-unwanted field-strength ratio (protection ratio) for Grade 2 interference. Each curve represents the average of the results from six observers. The results of Fig. 1 are summarised in Fig. 2 in terms of the protection ratio required in order that 80% or 50% of receivers shall not suffer interference rated worse than Grade 2. In the preparation of Fig. 2, the curves for both positive and negative frequency spacings in Fig. 1 were taken into account and treated as 20 separate sets of results.

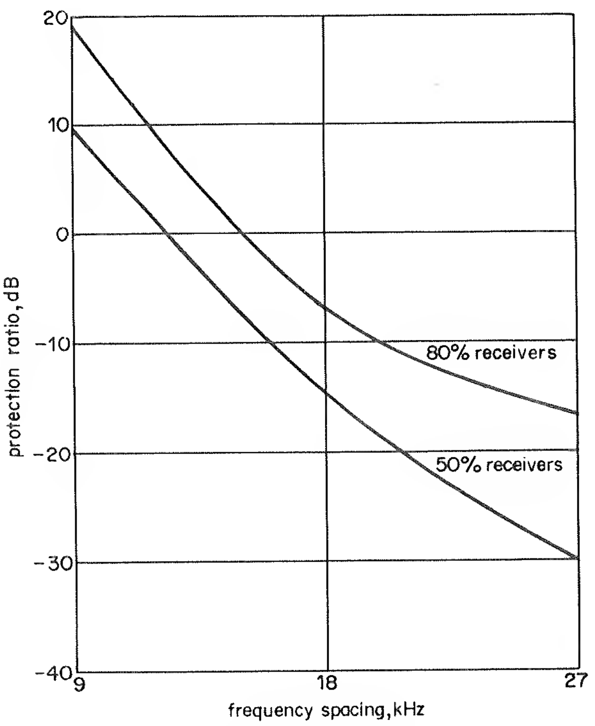

Fig. 2 - Close-channel protection ratio acceptable for Grade 2 interference

Similar tests were made on four receivers, A, D, G and J, with three observers, with a wanted-carrier frequency of 700 kHz. The protection ratio curve, as a mean value for all receivers and observers, is given in Fig. 3 together with the corresponding curve for the same receivers and observers extracted from the 1250 kHz results.

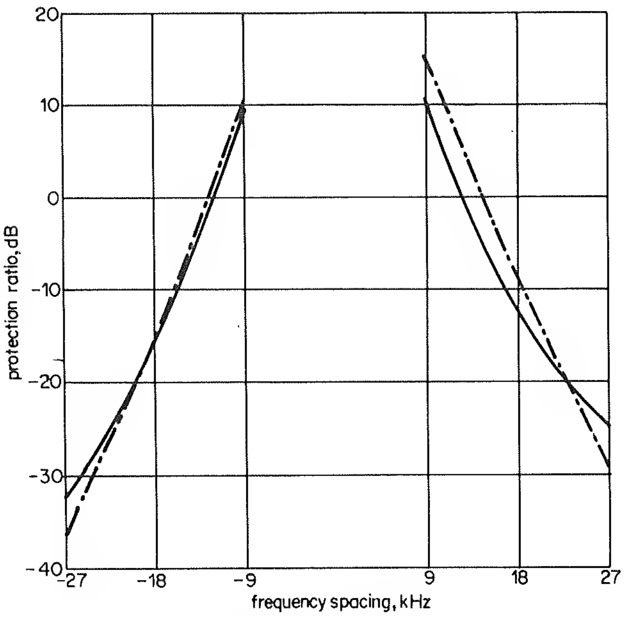

Fig. 3 - Close-channel protection ratio, average of 4 receivers, 3 Observers

——— Wanted signal frequency = 1250 kHz

— - — Wanted signal frequency = 700 kHz

When considering close-channel selectivity it is generally assumed that the protection ratio required is independent of the wanted signal level. Tests were carried out on six receivers to ascertain to what extent this assumption is justified. The results are given in Fig. 4, which shows protection ratio as a function of frequency spacing with wanted signal level as a parameter. These tests were made with one observer only and are hence subject to a rather higher level of experimental error.

This report is concerned primarily with absolute values of protection ratio. However, the concept of relative protection ratio, i.e. the difference between the protection ratio required for co-channel interference and that for an interfering signal at some stated frequency separation, is frequently used. To permit comparison between the results reported here and those quoted elsewhere in terms of relative protection ratios, the co-channel protection ratio for all ten receivers was measured and the relative protection ratios over the range 9 kHz to 27 kHz are given in Fig. 5. These results are the averages for six observers on each receiver and were obtained with a wanted signal of 10 mV/m at a frequency of 1250 kHz. The corresponding curve from CCIR Recommendation 499—1 is presented for comparison.[2]

3.2. Discussion of close-channel selectivity test results

The results shown in Fig. 1 illustrate the diversity of performance encountered in domestic receivers. There

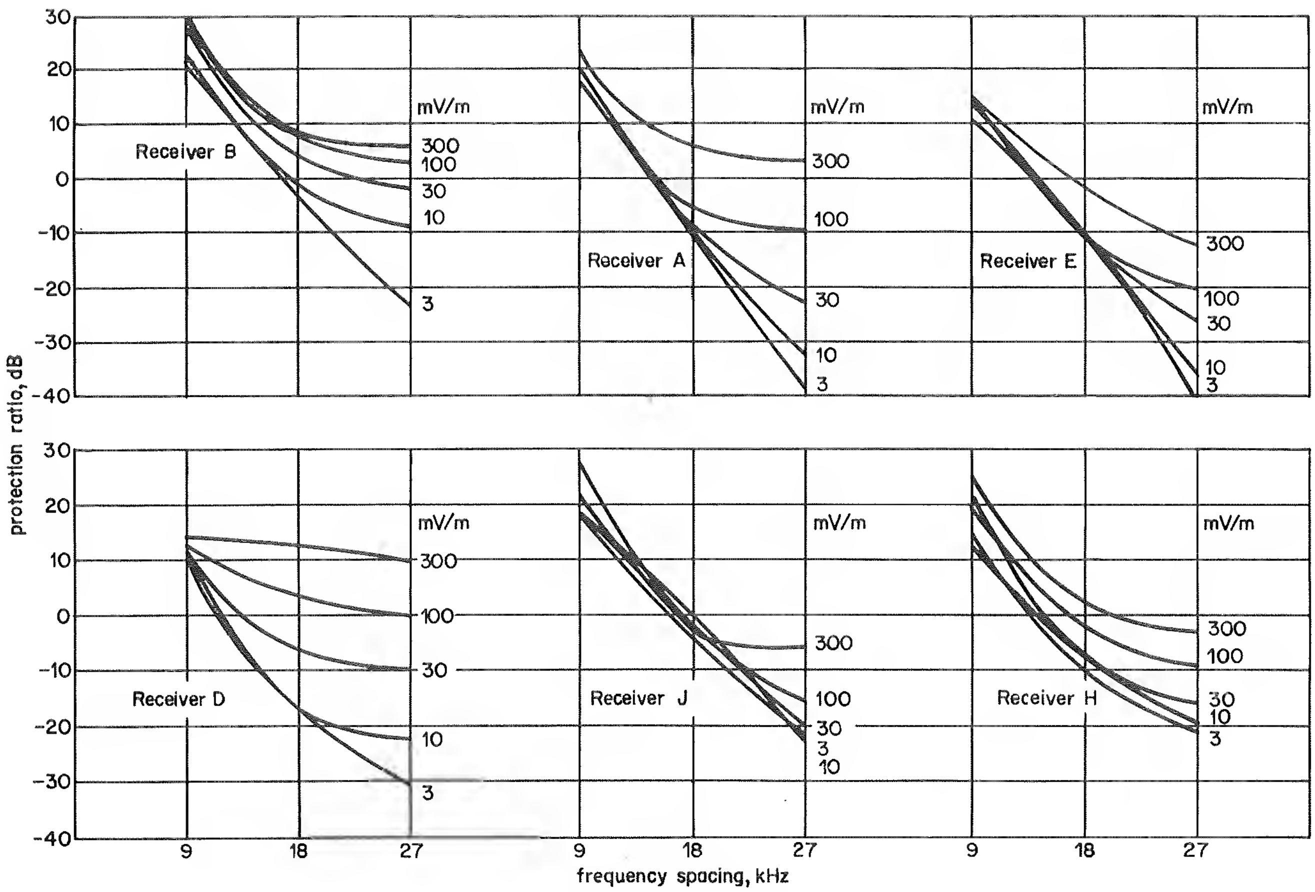

Fig. 4 - Effect of wanted signal level on close-channel protection ratio

appears to be no direct correlation between price and performance although the tendency of some of the more expensive receivers to require a rather high degree of protection, particularly at ±9 kHz, is probably partly due to the fact that their wider audio bandwidth and generally 'cleaner' sound makes the interference easier to perceive.

Fig. 3 shows that there is little difference between the close-channel selectivity of receivers at 700 kHz and at 1250 kHz, i.e. that the signal-frequency circuits, generally only a ferrite dipole, have little influence on the overall close-channel selectivity.

The relative protection ratios of Fig. 5 show slightly more correlation of performance with price than do the absolute protection ratios of Fig. 1. This is understandable since the influence of wider audio bandwidth and better quality of reproduction tends to be cancelled out in this form of presentation. The relative protection ratios are generally substantially higher than those in the CCIR Recommendation.[2] The results obtained for 9 kHz frequency separation, if we except those for receivers B, F and H that appear considerably poorer than average, show good agreement with the results of earlier investigations by BBC Research Department.[3]

The results shown in Fig. 4 indicate that the normally accepted protection-ratio data must be treated with some reserve in cases of close-channel interference to a fairly strong signal. They show that the required protection

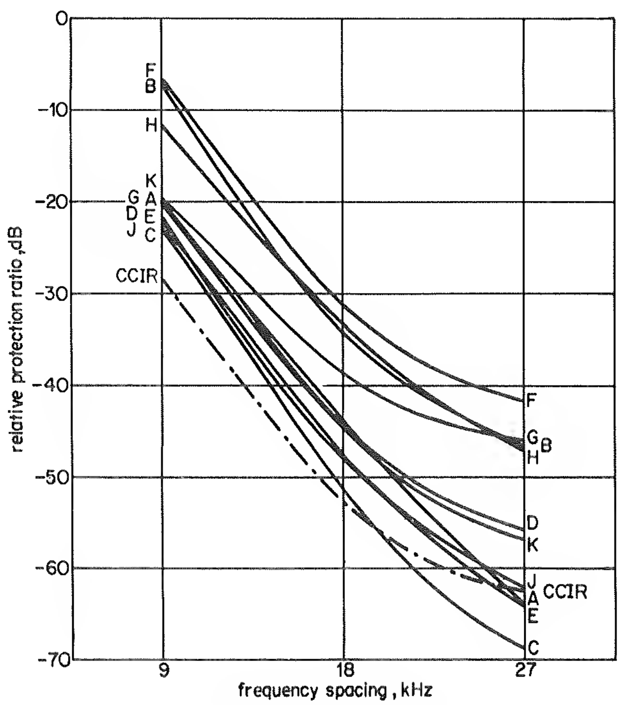

Fig. 5 - Relative protection ratios

ratio increases with wanted signal level. This effect is small at 9 kHz separation but becomes increasingly important as

the frequency separation increases. Receiver D demonstrates this most strongly. At 18 kHz separation for wanted signal levels above 10 mV/m, and at 27 kHz above 3 mV/m, the protection ratio is directly proportional to the wanted signal level, i.e. the level of interfering signal that can be accepted is independent of wanted signal level. The mechanism of this effect was not investigated but it appears likely that the interference occurring with the higher levels of signal results, not from lack of i.f. selectivity, but from intermodulation in the mixer stage and that this stage begins to overload with an interfering signal of approximately 60 mV/m at 18 kHz spacing and 100 mV/m at 27 kHz spacing.

3.3. Remote-channel selectivity test results

The bulk of the remote-channel selectivity tests were made in a similar manner to those for close-channel selectivity with a wanted signal frequency of 1250 kHz and field strength of 10 mV/m. The results are given in Fig. 6 and

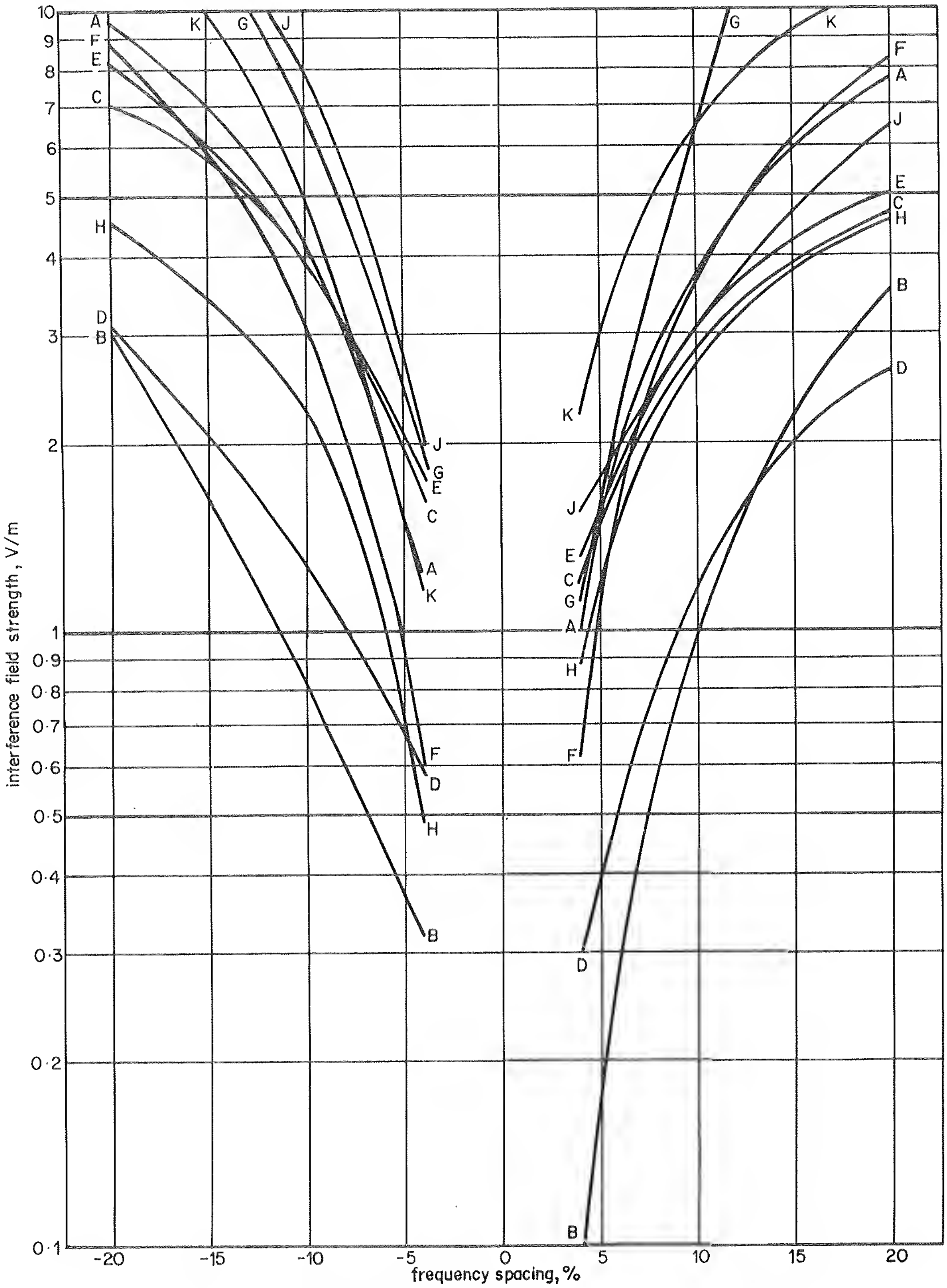

Fig. 6 - Remote-channel selectivity

Wanted signal frequency = 1250 kHz Wanted signal field strength = 10 mV/m

are summarised in Fig. 7 in terms of the absolute level of interfering signal that can be tolerated in order that 80% or 50% of receivers shall not suffer interference rated worse than Grade 2. Fig. 7 was prepared, as was the comparable close-channel curve of Fig. 2, by taking the curves for positive and negative frequency spacings in Fig. 6 and treating them as 20 separate sets of results.

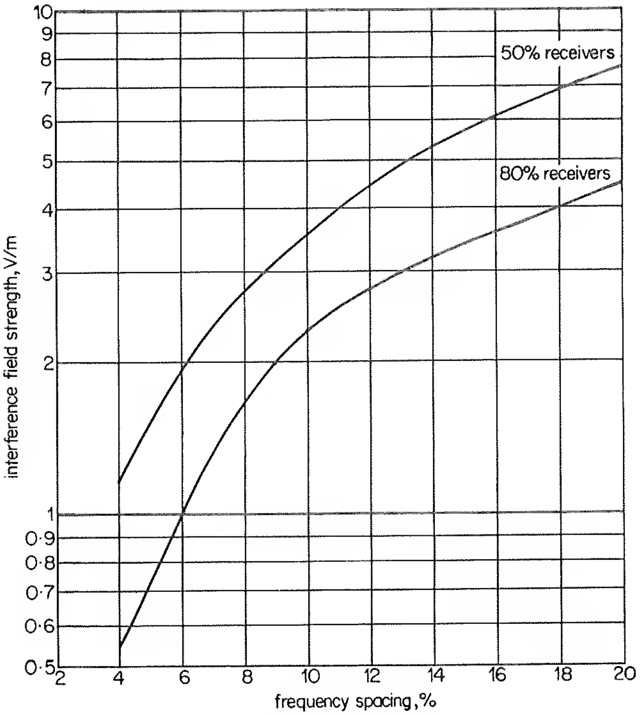

Fig. 7 - Remote-channel selectivity, level of interfering signal acceptable for Grade 2 interference

Similar measurements were made, with a wanted-signal frequency of 700 kHz, on receivers A, D, G and J using only three observers. The results are shown in Fig. 8 together with the 1250 kHz results for the same receivers and observers.

A further series of measurements was made with a wanted signal frequency of 1250 kHz and a frequency spacing between the wanted and interfering signals of 75 kHz (6%). The wanted signal level was raised in 10 dB steps from 3 mV/m to 1 V/m and at each step the interfering signal level for Grade 2 interference was recorded. Four receivers, A, D, G and J were used and all six observers took part. The results are given in Fig. 9.

3.4. Discussion of remote-channel selectivity test results

The remote-channel results are presented differently from those for close-channel interference in that they are plotted in terms of the absolute level of interfering signal and percentage frequency spacing as distinct from protection ratio and absolute frequency spacing. This is because the output signal-to-interference ratio over this range of frequency spacings is determined almost entirely by the strength of the interfering signal, the wanted signal level having little effect, as is demonstrated by Fig. 9. Also, from Fig, 8, it can be seen that remote-channel selectivity tends to be constant in terms of *percentage* frequency spacing irrespective of wanted carrier frequency.

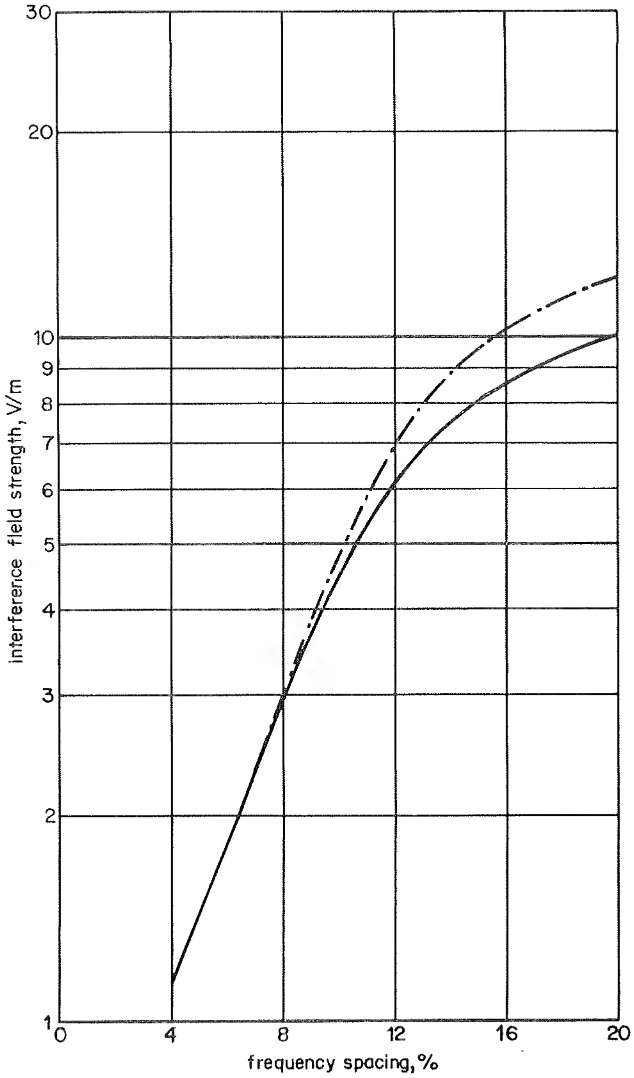

Fig. 8 - Remote channel selectivity, average of 4 receivers, 3 Observers

——— Wanted signal frequency = 1250 kHz
— - — Wanted signal frequency = 700 kHz

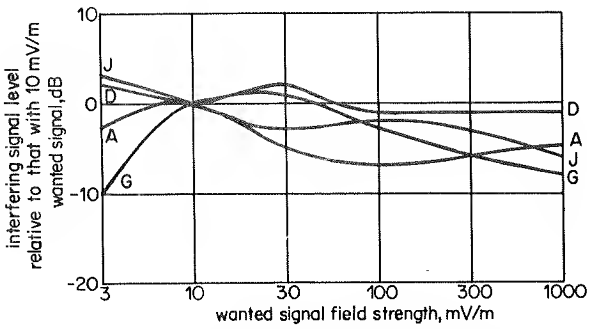

Fig. 9 - Remote-channel selectivity, variation of acceptable interfering signal level with wanted signal level

3.5. Additional tests

3.5.1. Slope of the subjective impairment curve

Measurements were made on four receivers A, D, J and G with six observers, to determine the change of subjective impairment with interfering signal level. With a wanted-signal frequency of 1250 kHz and field strength of 10 mV/m, the interfering signal was applied at the same frequency as the wanted signal ±20 Hz, and its magnitude adjusted until the observer assessed the impairment produced as Grade 2, 3, 4, 5 and 6 in turn. This test was repeated with frequency spacings between wanted and interfering signals of 18 kHz and 75 kHz (6%).

The results for the mean rate of change in dB per grade, for all receivers and observers, are given below.

Co-channel	4·8 dB per grade
18 kHz spacing	3·8 dB per grade
6% spacing	3·0 dB per grade

Considering first the results for co-channel and for 6% frequency spacing, the higher slope in the latter case is explicable on the assumption that the interference is produced by intermodulation in the mixer stage of the receiver when it is driven into non-linearity by the high level of interfering signal. The intermediate value of slope in the 18 kHz spacing case is probably caused by the fact that some receivers are tending to the non-linear state even at this close frequency spacing, as is shown by the curves of Fig. 4.

3.5.2. Maximum acceptable level of wanted signal

In an investigation of the behaviour of receivers in the presence of very strong local signals it is relevant to consider the maximum level of wanted signal that can be accepted without distortion in the absence of interference.

Preliminary tests indicated that the observers found it difficult to give consistent assessments of quality of reproduction. This was probably because the inherent distortion, particularly in the cheaper receivers, made it hard to formulate any absolute standard of judgement. The form of test finally adopted was to ask the observer to assess the wanted signal field strength at which the quality of reproduction was degraded by 2·5 grades on the 7-point comparative scale, i.e. between 'worse' and 'much worse', relative to the quality with a 10 mV/m signal. This test was carried out on ten receivers with six observers.

In view of the difficulty experienced by the observers in making their assessments and the spread of the results obtained — over 20 dB between the extremes on each receiver — some caution has to be exercised in presenting the results. However, it appears that, while the majority of receivers can accept a field strength of some 200 to 300 mV/m without serious distortion, few could operate satisfactorily at 1 V/m.

3.5.3. Effect of partially exhausted batteries

Throughout the measurements described in the preceding sections of this report the receiver batteries were checked at frequent intervals and discarded when the terminal voltage on load fell below the nominal value.

A separate test was made to determine the effect of partially exhausted batteries on remote-channel selectivity. For this test the battery was simulated in accordance with I.E.R. Publication 315-1 (1970), Clause 22, by a power supply unit producing the nominal battery voltage with a series resistor of such value as to drop the terminal voltage on load to the equivalent of 0·9 V per cell.

This test was carried out on four receivers, A, D, G and J, with three observers. No significant change in remote-channel selectivity was found.

4. Conclusions

Measurements have been made on a number of domestic transistor portable receivers on the m.f. range to determine their ability to reject interference from strong local signals. Two aspects of the problem were considered, viz. close-channel interference where the frequency spacing between wanted and interfering signals is between one and three channels (9 kHz to 27 kHz) and remote-channel interference where the spacing exceeds this.

With remote-channel interference the impairment produced by the interference is determined almost entirely by the level of the interfering signal at the receiver input, the level of the wanted signal having little effect. Provided that the frequency separation between wanted and interfering signals exceeded about 6%, 80% of the receivers tested could accept an interfering signal of 1 V/m without suffering an impairment graded worse than Grade 2 on the EBU six-point impairment scale.

With close-channel interference, the impairment produced is generally determined by the protection ratio, i.e. the ratio of wanted to unwanted signals at the receiver input, largely independent of wanted signal level. However, with frequency spacings of 18 kHz or more between the wanted and interfering signals, some receivers tended to require higher protection ratios as the level of the wanted signal was increased. It was also found that the close-channel selectivity of the great majority of the receivers tested was significantly poorer than is assumed in the CCIR planning data.

In the absence of interference, the majority of the receivers tested could accept a wanted signal field strength of 200 mV/m without significant distortion caused by overloading.

All of the measurements described in this report were made with the receiver oriented for maximum pick-up of both wanted and interfering signals. Interference or overloading produced by strong local signals could be ameliorated in the majority of cases by utilising the directional characteristics of the receiver ferrite dipole aerial.

The results reported here do not take into account the effects of spurious responses in receivers such as occur,

for example, when harmonics of the interfering-signal and the local-oscillator frequencies differ by the intermediate frequency. These can greatly reduce the level of interfering signal that is acceptable. When such a response was encountered in the course of the experimental measurements, the frequency of the wanted and/or interfering signal was adjusted in order to avoid it. If the generalised curves presented in this report are used for planning purposes it is therefore not sufficient to ensure that the general requirements of receiver selectivity are met. It is also necessary to examine each proposed frequency assignment to ensure that no arithmetical relationship exists between channels serving the same area that could produce a spurious response in receivers using the common values of intermediate frequency.

5. References

1. Signal injector for l.f. and m.f. receivers with ferrite-rod aerials. BBC Research Department Report No. 1969/41.

2. Documents of the CCIR XIIth Plenary Assembly, New Delhi, 1970, Recommendation 449-1.

3. Reduction of adjacent channel interference in the l.f. and m.f. broadcast bands by reduction of the modulation bandwidth. BBC Research Department Report No. 1971/10

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